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THE AMERICAN METEOROLOGICAL JOURNAL.

A MONTHLY REVIEW OF METEOROLOGY.

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NEW ENGLAND METEOROLOGICAL SOCIETY.

The twenty-fourth regular meeting was held at Nashua, N. H., April 23, 1892. Papers were read by Prof. W. M. DAVIS on "Meteorology in the Schools," Mr. R. DE C. WARD on "Thunderstorms in New England during the year 1886," and by Mr. J. WARREN SMITH on "The Storm of March 1 to 4, 1892."

METEOROLOGY IN THE SCHOOLS.

PROF. W. M. DAVIS, OF HARVARD COLLEGE.

IN the first chapter of Prof. Buchan's "Introductory Text-Book of Meteorology," published in Edinburgh in 1871, and still highly regarded in Great Britain, it is said: "In the schools of the United States of America, meteorological observations and the keeping of meteorological registers form a part of the common education of the people." I wish this were true, but, as far as my information goes, it is unhappily far from being the fact. On the other hand, Prof. Harrington, chief of our Weather Bureau, writing recently on meteorological work for agricultural institutions,* states that even in agricultural colleges "the subjects of meteorology and climatology are usually left as subordinate topics to professors of other branches, or entirely neglected."

Meteorology generally receives brief and insufficient attention as a chapter in the study of physical geography. Many of the text-books now in use are poorly adapted to giving a serious understanding of the subject. I do not regard them as

* United States Department of Agriculture, Experiment Station Bulletin.

insufficient because they fail to cover all the ground, for that cannot be expected in general teaching; but because they do not present the various parts of the science in such a manner as to give the scholars an adequate idea of their logical connection in the whole. Meteorology fairly deserves a higher place in general teaching than it now receives. It is a subject of great popular interest and importance. We live in its midst; examples of its processes are always with us. In its more elementary presentation it involves excellent opportunity for observation and record, such as help to train a child in habits of accuracy and neatness. The arguments of its demonstrations in a more advanced course afford suggestive opportunity for the application of logical methods to the explanation of natural phenomena on a large scale, after the principles involved have been learned in a smaller way in the laboratory study of physics and mechanics. The understanding of nature thus gained goes far towards clearing away some of the longest-remaining superstitions of the darker ages. Both in information and training, meteorology may claim a high place in the scheme of education.

My own experience in teaching this subject has been only in a college course, open to Freshmen, and therefore for the most part elementary, in the sense of requiring no previous knowledge of the subject itself. It is plain that a great part of this teaching might be carried down into the schools, if a place could be found for it; or, even if no more than the time now allowed to it can be given, a greater share of the serious part of the subject might be introduced by the teacher. A few instruments, a series of daily weather maps, such as are now readily obtainable from the stations of our Weather Bureau, and a well-prepared teacher will go far towards overcoming the deficiencies of the text-books ordinarily in use.

If the teacher has the courage to discard the text-book as a guide, and use it only as a reference book, let him begin at once with the weather maps, and explain in simple language the meaning of the signs of clear, fair, and cloudy weather, rain or snow, wind and calm, warm and cold. Pressure follows in a second lesson, while humidity had best be omitted until a later chapter. A blank map, on which the record for some interesting example of varied weather can be entered, may be filled out on the wall, before the class. Omit the isotherms and isobars

at first. Ask the class to describe the distribution of the various weather elements over the country. For example, the Lower Great Lakes may be cloudy and wet, while fair warm weather prevails along the Gulf coast, and clear cold air occupies the far Northwest. Let this be followed by a second example, in which the Gulf coast and the Northwest are cloudy and rainy, while the Lakes are clear. All manner of combinations may be discovered from the maps for a year.

In order to simplify the illustration of the distribution of temperature, suggest that a line be drawn, separating all parts of the country where the temperature is over 50° from the rest where it is lower. Then ask for other lines along which the temperature will be 40°, 30°, 60°, and 70°. When these have been talked about enough, propose that a name should be invented for them, for convenience of future use. Add isotherm to the suggestions from the class, and explain that this word is universally adopted. The class will then have gained an appreciation of a scientific term. It is a special word, used to name a particular thing. There is no difficulty with nomenclature when the need and use of it are thus introduced; and the lesson thus learned from meteorology will be found widely useful in other studies.

Atmospheric pressure must be introduced carefully. A few physical experiments may illustrate its reality; a brief series of barometric observations will demonstrate its variations. An empirical statement may be made to the effect that barometric readings must be corrected for various local influences, in order to make them comparable. Explanation of such corrections at this stage of the inquiry would be disconcerting; it belongs in a later chapter. Isobars may then be explained in the same way as isotherms. Lines of pressure-decrease curved so as to run at right angles to the curving isobars are instructive; they serve to impress the fact that the direction and rate of pressure decrease are both variable. When the varied facts of distribution of pressure have become familiar from the maps, a step may be made in looking for the correlations of various elements, which thus far have been described independently.

The wind is the most important of all the weather elements. The class should try to connect its course with the distribution of some other element represented on the map. At this stage,

every member of the class should have a separate map. If the school committee cannot afford so large a supply, it is seldom that some intelligent citizen cannot be found who will provide the few dollars that a year's maps will cost.

Competitive search and discovery constitute the most enlivening work that a class may engage in at school; and it must be indeed a dull class that will not contain several discoverers of the correlation now sought for. The class leaders soon perceive that the wind generally blows from regions of high pressure towards regions of low pressure; and the announcement of this generalization will turn all the others to its confirmation. The sceptics will announce that they find some winds that blow the wrong way; but if their search is extended, no doubters will remain. As confidence in the discovery grows, let the teacher ask if all are sure that nothing more need be said: does the wind really blow directly from high to low pressure? The sharper eyes now have to detect a most curious fact: a fact whose original discovery cost years of labor, but whose secondary discovery may now be repeated by a class of young children in the first week of their study of the weather maps: so successfully do the maps present the broad facts of nature, so difficult is it for the keenest investigators to perceive general relations from isolated observations. The wind does not blow directly towards low pressure, or along the line of pressure decrease, but turns systematically to the right of this line in by far the greatest number of cases. Our whole succession of weather changes will afterwards be found to depend on this simple statement.

The next subject for correlation is the velocity of the wind. This requires more careful study, but it yields to close scrutiny. Do not violate the right of discovery of the brighter scholars by telling them what they may find out for themselves. Let them learn the value of perseverance by reaching the goal to which it leads. When the correlation of high winds with rapid decrease of pressure is found out, take particular pains not to introduce a technical formulation of it too soon. Do not say the wind increases with the gradient; but let the class attempt the careful formulation of the correlation. If some of them can accomplish this, they will have learned more in real living values than would be gained in memorizing a whole chapter of text;

for they will have made the text for themselves. It is important that this should be impressed upon scholars; it will greatly aid in giving reality to paragraphs that are sometimes regarded as dull.

The formulation of the preceding correlation may be in such phrases as follows: the wind blows faster where the isobars are close together; the wind blows faster where the decrease of pressure is more rapid; but it is hardly to be expected that any will say: the winds blow faster where the rate of decrease of pressure is greater. For some reason, probably known to teachers of arithmetic, the idea of the *rate of change* is not easily grasped; therefore do not in this case allow the class to hear the term *gradient*, the shadow of the idea, until they have surely acquired the idea itself.

I cannot here delay on the various other correlations that should be worked out. They may be briefly mentioned: circulation of wind with distribution of pressure (areas of high and low pressure); areas of high and low pressure with weather (clouds and rain); direction of winds with variation of temperature; temperature with areas of high pressure in winter and summer; and so on. Many of these may be hastened by the introduction of exceptionally good illustrations of the facts on which they are based. Then, and not till then, introduce the words, *cyclone* and *anticyclone*, as names of the areas of low and high pressure, with their accompanying weather features. The progression of these areas across the country may then be examined, and the accompanying weather changes worked out. Elementary practice in the explanation and prediction of local weather changes may then be attempted with profit.

Experience has shown that it is useful to introduce early in the course, and in connection with some of the foregoing practical exercises, an account of the vertical decrease of temperature in the atmosphere, and of some of its significant variations with the seasons and with different weather conditions. A graphic construction may be employed for the convenient representation of this subject.* This is not closely connected with the elementary study of the weather maps; it is not brought in here

*Temperature Diagrams. American Meteorological Journal, August, 1885. These diagrams should be reversed, right and left; so as to bring higher temperatures on the right.

from its pertinent relation to the other subjects of this chapter, but in order to give the class an early encounter with it, so that when it comes up again, as it will frequently enough, they may meet it as an old acquaintance.

I have found it an advantage not to hold the class on this kind of work till it is all completed, before advancing to the consideration of other subjects. It is more enlivening to introduce some account of the composition, offices, and arrangement of the atmosphere after the work of correlating is well begun, and to keep the two lines of study advancing abreast. The like and unlike relations of plants and animals to the atmosphere make an interesting subject for explanation. Then take up the arrangement of the atmosphere around the earth; and while this is going on keep close at hand the text-books on physics, in order to refer frequently to them and recall what has already been learned about gases, expansion and compression, gravitation, centrifugal force (that stumbling-block of all who learn from words and not from experiment), gravity, and the like.

It is serviceable to place some general question before the class during this advance; for example, Why does the wind blow? The correlations of the wind with other weather elements are studied from the maps; but the reasons for its blowing require another kind of investigation, in which the correlations taken from the maps are to be confronted with the principles of physics that they involve, and after thorough inquiry, an explanation that satisfies all requirements is to be made out. If stated in a simple form, this principle may be introduced with young classes, and by keeping their minds alert for discovery and explanation the stupefaction following too continuous employment of text-book and recitations may be successfully avoided. A fair share of real learning may thus be introduced even with young scholars; and this is not the least of the advantages of the subject and method as here outlined.

Why does the wind blow? Can it be on account of the attraction of the earth on the atmosphere? Let us see how such an attraction would affect the ocean, where the visibility and incompressibility of the water make the problem simpler. A liquid, like the ocean water, will adjust its surface to a position at right angles to the forces acting on it. Try this with a plumb-line and a dish of water, and see for yourself that the attraction of

the earth, or terrestrial gravitation, everywhere draws the waters of the ocean towards the centre of the earth; and the only form that a water surface can take, when it lies everywhere at right angles to a system of forces which all intersect at a single point, is a spherical form. When thus adjusted, the ocean would be calm, not moving; and the atmosphere would, in a similar manner, lie level and quiet if only gravitation were working upon it.

A useful conception of the arrangement of the isobaric surfaces of the atmosphere may be gained through the ocean. This is important if the scholars are to gain a real understanding of the isobaric lines on the weather maps. The ocean's quiet surface, under the action of gravitation alone, is everywhere pressed upon by the atmosphere; that is, it is everywhere under the pressure of one atmosphere. It has been learned from physics that this is equivalent to about thirty-four feet of pure water, or thirty inches of mercury; or something over thirty feet of salt ocean water. Descend thirty feet under the calm ocean surface, and there a surface, spherical like the upper surface and concentric with it, may be imagined, on which the pressure is two atmospheres. Every thirty feet an atmosphere of pressure is added; and as water is almost incompressible, the shells into which the ocean's mass is thus divided will be of almost the same thickness at the bottom, where the pressure may be several hundred atmospheres, as at the top, where it is only one.

But the atmosphere is a highly elastic gas; hence its isobaric surfaces cannot be equidistant. The barometer should have been already shown when the pressure records of the weather maps were first mentioned; although its explanation in more detail may be postponed much later. The essential principle in the construction of the barometer should be again illustrated when the idea of the pressure of the atmosphere on the level ocean's surface is presented. It is now referred to a third time. As mercury is 10,784 times as heavy as sea-level air, a column of air about nine hundred feet high will correspond to an inch of mercurial pressure. Hence at the height of nine hundred feet the barometer would read only twenty-nine inches; and air would therefore be only twenty-nine thirtieths of its density at sea level. About a thousand feet higher the pressure would be twenty-eight inches, and the air there would have a density only

twenty-eight thirtieths of that at sea level. The famous experiments of Torricelli and Pascal should be recalled in this connection. If there is no hill near the school-house, let the scholars carry the barometer from the basement to the roof, and thus estimate the height of the building.

The vertical decrease of density in the atmosphere will become appreciated by this gradual introduction. Balloon voyages and mountain ascents may be quoted in confirmation of the deduction from physical principles. The meaning of deduction may be thus illustrated, just as induction and generalization have been before, although the terms should not be introduced with young classes.

Gravitation alone having been found incapable of maintaining the continued movements of the atmosphere, ask the class for another suggestion : May the rotation of the earth, perhaps, have some effect? It is worth while to give careful attention to this question, if any one may judge by the vague conceptions concerning it, possessed by persons who would otherwise be regarded as intelligent. The effect of the earth's rotation is to introduce a system of centrifugal forces, all acting outward in the plane of the latitude circles, and increasing from zero at the poles to about one three hundredth of gravitation at the equator. Draw a large meridional section of the earth ; indicate the forces of gravitation by a series of centripetal arrows, and the centrifugal force at various latitudes by smaller arrows, of appropriate length and direction. Construct the local resultants of the pairs of forces for a number of different points, and then ask for a general statement concerning the attitude of these resultants, and the form which the ocean would assume under them. The ocean's surface must take the form of a flattened sphere or oblate spheroid : no other form is possible. All its imaginary isobaric surfaces will also be spheroidal ; so will those of the atmosphere. When thus rearranged, the atmosphere and ocean must remain at rest under the joint action of gravitation and centrifugal force, or *gravity*, as long as the earth's rotation is constant. The earth's rotation cannot be appealed to as a cause of the winds. When a scholar is reminded that the centrifugal force is busy holding up thirteen miles of ocean water and a corresponding amount of the atmosphere at the equator, he may perhaps better perceive

why this force cannot be called upon to do something else as well.

The air lies for the most part on the level surface of the ocean ; islands and continents with their mountains and plateaus project upwards into it, displacing it from the space that they occupy, but not causing motion any more than the similar projection of islands and continents from the floor of the ocean causes the ocean currents. The cause of the winds is not yet introduced.

It may be stated here to the class that if the air lay evenly over the world there could be no isobaric lines on the imaginary sea-level surface to which the barometric data for the weather maps are reduced ; the pressure would everywhere be equal. As a matter of fact, the weather maps have made it clear that the pressure varies both in place and time. The variation is, to be sure, of small amount ; and yet upon that small amount it has been found that the wind depends, both in velocity and direction.

Some other means of maintaining the movements of the atmosphere must be devised. The circulation of air in flues and chimneys may be mentioned to suggest the possibility that a difference of temperature between certain parts of the atmosphere may introduce the conditions of motion. Then, as before with gravitation and centrifugal force, the suggestion must follow the lead of the physical principles involved, in order to learn the consequences that follow from it. The accordance of of these deductive consequences with the facts of nature will enable the students to come to a just judgment as to the sufficiency of the new cause of the wind.

I shall not here delay the reader with a statement of the ordinary scheme of convectional motion under the combined action of differences of temperature and gravity, but will call attention only to the more important applications of this general physical problem to the case of the atmosphere.

Assuming that a certain part of the atmosphere is warmed above the temperature of its surroundings, a convectional circulation will be established, with inflow at the base, ascent about the centre, outflow aloft, and descent in the periphery. The warmed area will have a lower pressure than the surrounding regions, and the isobaric surfaces that were level and

essentially parallel under the action of gravity alone are now deformed under the combined action of differences of temperature and gravity. This should be illustrated by a vertical section of the atmosphere through the warm region, showing the outward gradients aloft and inward below. Notice that the isobaric surfaces diverge on entering the warm region. If the area of the warm region is circular, a system of concentric circles may be drawn on a plan of the region to represent the distribution of pressure at sea level; the movement of the centripetal surface winds may be added to the same figure.

If the supply of heat, by which the local excess of temperature is excited, be constant, then a certain velocity of circulation will be assumed and maintained; this will introduce the conditions of *steady motion*, when the resistances and the accelerating forces are just balanced; an instructive problem in meteorology. The greater the differences of temperature the greater the gradients and the faster the winds. If the source supply of heat varies periodically the distribution of pressure and the flow of the winds will vary in the same period, but the epochs of change will be a little later in the effects (winds) than in the cause (temperature).

If a certain region be alternately warmer and colder than its surroundings, it will have low pressure with inflowing winds and high pressure with outflowing winds alternately in the same period. Of all these considerations, that concerning the conditions of steady motion deserves the most careful attention.

The last suggestion as to the cause of the winds may now be tested by confronting its consequences with the corresponding facts; and this will be taken up after a time. The apparent agreement of the isobaric lines of cyclones and anticyclones with those of regions of high and low temperature justifies a provisional confidence in the suggestion, although the class should be carefully warned not to accept such apparent correspondences as final proofs until a large variety of other consequences are also examined.

The apparent success of differences of temperature as a cause of atmospheric circulation now requires that the causes of variation of temperature over the earth and through the year should be examined. I would call particular attention to the sequence of subjects thus introduced; the reason for their order being the

need of understanding them, and not their arrangement in a text-book. Although there will always be scholars who fail to apprehend the logic of the study, there will be others whose intelligence gives them an appreciation of the course of the work. Their minds are thus opened to responsible activity, and diverted somewhat from passive obedience to the commands of the printed page.

The heat of the earth's interior, the sun and the stars may be mentioned as the possible controls of atmospheric temperatures, and a brief consideration of the variations of heat from day to night, from winter to summer, and from equator to poles will convince the class that the sun is the only one of these that needs further consideration. A most interesting chapter is now opened in the effort to understand how the heat of the sun can affect the earth across ninety million miles of empty space. The undulatory hypothesis of radiant energy must be presented in outline; careful distinction must be made between heat and radiant energy. At the same time, the astronomical relations of the earth to the sun should be illustrated.

The need of this is apparent after a few questions are asked regarding the form of the earth's orbit or the cause of the seasons, the location of our summer and winter on the orbit, and so on. The ignorance prevailing on such matters is only an illustration of the general study of words and not things. A card-board, two pins for the foci of an eclipse, a thread to guide a pencil, a scale of millions of miles: with these simple properties an orbit of true proportions may be constructed, perihelion and aphelion, the solstices and equinoxes all located. A ball is then added to represent the (magnified) earth; a paper ring, fitting the ball, shows the twilight circle, dividing day from night, and with this small outfit, the zones and the seasons may be really understood. I recall an amusing experience over this practical exercise a few years ago, with a class of teachers, all over twenty years of age. Hardly a member of the class could locate the winter solstice correctly, and but few could locate the equinoxes, although nearly every member of the class could define the various terms as stated in the books.

Some account must now be given of the action of that small part of solar radiation that is incident on the earth. Experimental illustration may be made of reflection, transmission, and

absorption; specific heat and latent heat must be explained; and on this basis the action of sunshine on the air, the land, and the sea may be properly considered. In the same connection, the action of conduction and local convection should be brought in, to show the dependence of atmospheric temperatures on the temperature of the surface beneath. The conditions of local convection, that is, of atmospheric instability, deserve particular attention. They may be graphically illustrated by an extension of the temperature diagrams already referred to.* The application of the principles thus learned will be called for in connection with various special phenomena of the winds further on.

Thus prepared, the actual distribution of temperature over the earth may be examined. I introduce at this point an account of thermometers and thermographs, and briefly discuss methods of exposure and observation. The subject is then pertinent to the general progress of our inquiry; it is not needed sooner, for every scholar may understand the weather maps without more instruction in thermometry than is gained from a thermometer hanging outside of a window. The various statistical records, such as mean monthy and mean annual temperatures, are also explained.

The isothermal charts for the world follow in order: one for the year, others for the opposite seasons, or for January and July. Notice that these isotherms are "reduced to sea level." The series of monthy isothermal charts of the world, prepared by Buchan for his report on the meteorology of the Challenger expedition, are a luxury at this point of the course. The maps for January and July are now coming to common use in the newer editions of English geographical text-books. Hann's charts in Berghaus's Physical Atlas are also excellent. The most useful manner of studying these charts is to analyze the distribution and variation of temperature with regard to cause. For example, first, the high temperatures of the equator and the low temperatures of the poles are the result of the distribution of sunshine over the earth, as studied out by means of the wooden earth on the elliptical orbit. Second, the line of highest temperature, called the mean annual heat equator, is

* See American Meteorological Journal, Jan. and Feb., 1890.

found to lie somewhat north of the geographical equator, and to be marked by higher temperatures on land than at sea. The cause of the latter inequality is found, not in the lower specific heat of land than of water, for we are considering mean annual temperatures, but in the attempted equalization of polar and equatorial atmospheric temperatures by the ocean currents, while no such attempt is made on land. Third, the isotherms do not follow precisely along the lines of lattitude, as they should, according to the mean annual distribution of sunshine; they depart by a greater or less amount from symmetrical position, least in the watery Southern Hemisphere, most in encircling the northern alternations of land and water. The ocean currents must be here introduced again, with some brief statement of their courses. This is most easily done by generalizing the eddy-like turning of the currents in the several oceans. The North Pacific has a simple eddy, almost closed from other oceans. The North Atlantic is most irregular, receiving a great branch from the South Atlantic, giving out a great branch to the Arctic, of which a partial return comes down by Greenland and Labrador. In this connection, it may be hinted that it is wrong to connect the currents of the Indian Ocean with those of the Atlantic around the southern point of Africa, and that a large part of the warm waters that bathe the coast of Norway have not made the circuit of the Gulf of Mexico, but have passed along the outer side of the Antilles, and hence do not strictly belong to the Gulf Stream.

The seasonal isothermal charts are most interesting in the contrast that they present between the great variations from summer to winter in the Northern, or Land, Hemisphere, and the small variations found in the Southern, or Water, Hemisphere; in the slightly lower mean temperature of the whole earth in January, when nearest the sun, than in July, when farthest from the sun; in the annual oscillation of the heat equator, following the sun north and south; in the curious migration of the pole of greatest cold to northeastern Siberia in January, and so on. Charts of anomalous temperatures and of areas of equal annual range of temperature are instructive, but may delay the class longer than is admissible.

The subject is now developed to a point at which an intelligent scholar, who has learned his lessons well, may be asked to

pass judgment on the theory that the movements of the atmosphere are essentially convectional. If he readily concludes that such is the case, ask him, How do you know you are right? Perhaps he may quote the book; if so, turn to some paragraph, usually to be found in text-books, in which an erroneous statement is made, show its error, and ask, May not the statement about convection be wrong also? If he falls back on the manifest acceptance of the theory by the teacher, frankly admit that even the teacher may be wrong, and insist that the only admissible ground for belief is that on which conviction follows logical argument and demonstration. It is an easy matter to make a class recite that the trade-winds blow thus and so; it is quite another matter for them to possess and assimilate the argumentative demonstration by which they can support their beliefs, and without which their beliefs are probably more hindrance than aid to an intelligent development of the mind.

The method of investigation to be followed must be clearly appreciated. It is worth learning, for it is useful in all other studies, and in all walks of life. It has nothing of prejudice; it has nothing of special pleading or favoritism, such as too often unwisely enters political argument. It should be as cool as geometrical analysis, and, if possiple, as conclusive. The method finds no better illustration than in the next step in this scheme of teaching meteorology.

The fact that the winds blow is well known from ordinary observation at home; it is also known from the more extended study of the weather maps. General reading may have already introduced something about the trade-winds, or of the brave west winds of the Southern Hemisphere; the more the better. But among all these facts, only those derived from the weather maps are as yet correlated with other facts.

On the other hand, it has been deduced from the principles of physics that, if there is any truth in the theory of the general convectional origin of the winds, they must converge towards regions of high temperature, where the pressure will be low, and they must blow out from cold regions, where the pressure will be high. They must blow faster when the differences of temperature under which they move are increased, and slower when the differences are decreased. They must flow alternately in and out from a region whose temperature is alternately higher

and lower than its surroundings. All these varied deductive consequences of the simple convectional theory may now be applied to the case of the actual earth, both for mean annual temperatures, and for the seasonal and diurnal extreme temperatures. It is absolutely essential for good results that this application should be made before the charts of winds and pressures are examined. I do not mean that the teacher shall forbid the inspection of such charts, but that the scholars should sincerely appreciate the problem before them, even to the point of themselves refusing to look at the wind charts until they have independently studied out what the winds of the world ought to be if the convectional theory is correct. Only in this way will the deductive extension of the theory be impartially carried to all its legitimate consequences.

If the varied mental activity among the scholars has become somewhat apparent before this, it is conspicuous from this time forward. There are unfortunately always some who, from carelessness in previous studies which they then interpret as finding new work difficult, or from laziness, or unhappily from inherent dullness, fail to apprehend the course of the work from this time on. They learn something. They recite the facts, but they lose the spirit. On the other hand, the well-trained members of the class now rise to the excitement of the chase after truth. They will no more look at the wind charts before their deductions are made out than they will cheat in a game of ball. The teacher may ask these successful students for an outline map of the world, on which the predicted system of pressures and winds, annual and seasonal, shall be charted in rough manner, sufficient only to test the theory. For the mean of the year, the equator will be drawn with low pressure, and the poles with high pressure; and the surface winds will be marked as flowing along the meridians towards the warm equatorial region of low pressure. This simple scheme will be interfered with by the continental variations of temperature with the seasons. The lands will be indicated as centres of high pressure and outflowing winds in winter, of low pressure and inflowing winds in summer. The equatorial belt of low pressure will shift north and south after the sun, following the migration of the heat equator. Diurnal winds may be added in a verbal statement, but not introduced on the charts.

While the class is at work on this scheme the methods of observing winds and pressure may be briefly described and practised. Then the wind and pressure charts may be examined; as before, those by Buchan or Hann are the best.

In a general way, there is an accordance between prediction and fact. There is lower pressure at the equator than on either side, and the belt of low pressure has an annual migration north and south over a few degrees of latitude. The winds flow towards the belt of low pressure from either side, but obliquely, instead of along the meridians. The continents exhibit annual fluctuations in the sea-level pressure over their centres, and in the course of their winds, although the winds are oblique. But about the poles, where a persistent and dominating high pressure was expected, the pressure is lower even than at the equator; and between poles and equator there are belts of high pressure, best shown in the Southern Hemisphere. I presume there will be some who will not altogether sympathize in the pleasure that the result of the comparison of fact and prediction always affords me. The pleasure is not in the discomfiture that the scholars feel at the failure of complete accordance between fact and prediction, but in the manner in which the more energetic minds recognize that there is a real problem before them, where, perhaps, they thought there was only a foregone conclusion, and in the effect that this has on their mental attitude. Some are overcome; they let the matter drop, and lose interest until further explanation is offered, because the question is not so easy as it seemed; but the best workers attack the difficulty with good spirit and accept the proper responsibility of the earnest student. These are the teacher's rewards for his efforts.

The plan that I have adopted for advancing over this critical stage in the study may be outlined as follows: The discrepancies between the consequences of theory and the facts are of two kinds: First, the prevailing departure of the winds from the line of the gradients, which recalls one of the earliest correlations of the weather maps, and greatly extends its application; second, the occurrence of low pressures around the poles, flatly contradicting the expected results of the convectional theory. This contradiction must not be glossed over. Any clear-headed scholar would be justified in discarding the whole theory, if so glaring an inconsistency as this were left unac-

counted for. When these two classes of discrepancies are perceived the class may be asked whether they regard the convectional theory entirely at fault, or simply incomplete. No one who appreciates the physical conditions of convection can doubt that the theory is applicable in the atmosphere ; therefore its failure to account for all the facts must be due to omission rather than to fundamental error.

If one of the two classes of discrepancies can be shown to depend on the other, then the discovery of a cause for the latter will solve the problem. Notice, therefore, the general circulation of the winds of the Southern Hemisphere. Beyond latitude thirty degrees south the surface winds, and the upper currents also, as far as they are revealed by scanty observations of clouds in those remote regions, all possess an oblique easterly motion. Suppose we should rise above the South Pole and there gain a general view of the circulation established around it : it would constitute a great circumpolar eddy or whirl, turning faster than the earth turns. The same arrangement can be perceived in the Northern Hemisphere, but less distinctly, because the general circulation is there so seriously interrupted by the continents and the mountain ranges. What effect must these polar whirls have on the distribution of pressure? They must withhold the atmosphere from the centre of the whirls, and thus require it to accumulate in belts at some latitude between the poles and the equator. That is, the deflection of the winds from the gradients requires just such departures from the expected distribution of pressures as are found on the barometric charts, and whose first discovery proved so puzzling. The problem will therefore be fairly solved if a cause for the systematic deflection of the winds can be found.

Why should the winds depart systematically from the gradients, to the right in the Northern Hemisphere, to the left in the Southern? There are various methods of illustrating the general principle here involed ; but the most appropriate to the especial aspect of the problem under consideration may be made with a vessel of water, having a vent at the bottom, and set upon a whirling table. If the water stands still when the vent is opened, the discharge is accomplished quickly by radial inflow from margin to centre ; but if the vessel be rotated before opening the vent, then the discharge will be accompanied by the

formation of a rapidly whirling eddy with an empty core at the centre, where the surface of the water will be much depressed; and the time of discharge will be much lengthened. In a very rough way, this corresponds to the overflow of the upper currents from the heated belt around the equator towards the cold polar centres of the atmosphere. If the earth did not rotate, the circulation between equator and poles would be along the meridians; and in such case, there is every reason to think that the pressure at the poles would be higher than elsewhere; but on a rotating earth the circulation must be accomplished on oblique lines, and the polar high pressures that would be produced by low temperature are reversed into low pressures by the centrifugal force of the circumpolar whirl. The air thus withheld from the polar regions is seen in the tropical belts of high pressure.

As my readers are probably aware, this great generalization is due to Prof. Ferrel, and its fuller discussion was his greatest work. Its introduction into meteorology revolutionized the science.

I cannot now delay on the somewhat involved account that has to be given of the oblique courses of the terrestrial circulation. Its proper presentation and illustration are matters of difficulty, and must be reduced to their simplest terms for school use. The ordinary statement about the *lagging* of the trade-winds is objectionable, and should be improved. In higher instruction, the proper discussion of this subject should not be omitted by any teacher who desires that his scholars shall carry away just ideas.

If the terrestrial winds are well apprehended, no difficulty remains through the rest of the subject. The convectional theory of the winds, modified by the effects of the earth's rotation, and by the presence of water vapor, carries the class over all the remaining chapters of the science. A classification of the winds according to their causes may be here introduced to advantage, for the purpose of giving definiteness to the account of the various movements of the atmosphere.*

A new chapter now introduces the occurrence of water vapor in the atmosphere; its source, its production, measurement,

* American Meteorological Journal, March, 1888.

distribution, and condensation. Under the latter heading, I always have difficulty with the terminology of clouds, a subject that is still in an unsatisfactory shape for the teacher; but by means of lantern illustrations from photographs of clouds, of which I have now brought together a useful collection from various parts of the world, this difficulty is lessening.

The distribution of rainfall as shown on Loomis's rainfall chart of the world offers a new means of testing the general theory of the winds; for as condensation of vapor depends in all cases on the movements of the atmosphere, it is possible to establish a very close correlation between the two. Thus we have a rainy belt in the equatorial calms, and a relatively dry belt in the calms of the tropical belts of high pressure. This is precisely what the theoretical explanation of these belts would have led us to expect. On the western coasts of the continents, about latitude thirty-five degrees in either hemisphere, there is a region of rainy winters and dry summers; and this is most beautifully consonant with the seasonal variations of the terrestrial circulation, modified by continental interruptions.

In connection with the production of clouds and rain, attention should be called to the retardation of the cooling of poleward or upward currents, when the condensation of vapor liberates latent heat. This forms a most important supplement to the conditions of convectional action, as already formulated in an earlier chapter. The class then passes naturally to those irregular disturbances roughly grouped together under the vague term, storms.

The most important question in this chapter concerns the part that normal convection should be allowed in the explanation of cyclonic storms. A few years ago, the most generally expressed opinion classed all cyclones as convectional whirls, in which the liberation of the latent heat from the condensing vapor played a large part; but in the past two years there has been a division of opinion on the subject, and a number of writers have followed Dr. Hann in regarding the cyclonic storms of temperate latitudes at least as due to eddies driven by the general circulation of the atmosphere, and not to spontaneous convectional action. The simplest and most direct argument in favor of this view is the increase in the number and intensity of cyclones in temperate latitudes in the winter season; this

being the case in the Southern as well as in the Northern Hemisphere. If they were of convectional origin, they should be most frequent in summer, like the undoubtedly convectional thunderstorms. In winter the vertical decrease of temperature is generally slow, thus weakening the opportunity for convection ; and the retardation of cooling in ascending currents by the liberation of latent heat is much less effective at the low temperatures of winter than at the high temperatures of summer. Add to this the results of mountain observations, as summarized by Dr. Hann in the last two years, from which it appears that cyclones are as a mass colder than anticyclones, and it is manifest that the convectional theory as ordinarily apprehended is not applicable to such disturbances. In cyclones of the torrid zone, however, convectional action appears to be dominant as they are at present understood.

To my mind, this element of uncertainty in the explanations of various phenomena is not objectionable. There is enough that is well demonstrated ; the rest, which at present must be held as unfinished work, serves as an antidote to the craving for final truths, so characteristic of the student mind. The world is full of uncertainties ; and the well-trained scholar should be somewhat prepared for meeting unsettled questions in real life by encountering some unsolved problems at school, and holding his mind undecided in regard to them.

Cyclonic winds, local storms, weather and climate furnish headings for further work that can here be only named.

This outline necessarily omits many important subjects ; but perhaps enough has been stated to show how a well-rounded course of meteorology may be developed, and how at the end of it the class returns to the beginning, and finds in the problems of the weather changes from day to day the most difficult problems of the science. The correlations determined from the weather maps hold good throughout the whole course of study ; but the complete solution of weather changes is far beyond the meteorology of to-day. A student trained seriously by his own efforts as well as by his teachers, in a course of study thus planned, will gain some insight into the meaning of scientific investigation ; he will recognize the great difficulties attendant on the successful prediction of the weather ; he will learn to be patient with the errors that must for the present and for years to

come lessen the value of our official weather predictions ; while he may be justly impatient with those who pretend to outline the course of meteorological events for months ahead, and who thus live on the credulity of the public. He will not be easily deceived by the vain pretences of the rain-makers, or misled by the grossly exaggerated reports of their pretended successes. He will perceive and appreciate the course of natural events around him so far as to gain intelligent pleasure from them, and thus be prepared, as far as such training allows, to take his proper place in an educated community.

THUNDERSTORMS IN NEW ENGLAND DURING THE YEAR 1886.

R. DE C. WARD.

THE observation of thunderstorms was taken as a special subject of investigation by the New England Meteorological Society during the summer season of 1885, 1886, and 1887. The records of 1885 have been reviewed by Prof. W. M. Davis, and the results published in the " Proceedings of the American Academy of Arts and Sciences," Vol. XXII., July, 1886, and reprinted in pamphlet form. The results derived from the study of the records of 1886 and 1887 will shortly be printed in the Annals of the Astronomical Observatory of Harvard College, and this report is offered as a preliminary statement of what will there be dealt with at greater length.

The general plan followed in this work has been the same as that adopted by Prof. Davis. The times of rain beginning and loudest thunder were charted for each day on which storms occurred, and lines were then drawn marking the half-hourly position of the rain front. From an examination of these lines, the general direction and extent of the storms were determined. The scheme of classification adopted divided the disturbances reported into two classes : storms which had distinct movement, and those which were only noted as scattered records of thunder, apparently not connected with moving storms. In order to determine the relation of these local storms to the larger cyclonic storms which continually travel across our country,

and to bring this investigation to form a basis for the prediction of thunderstorms in this section, if possible, particular attention has been paid to the conditions of pressure accompanying such disturbances.

The following table gives the number of days in each month on which reports were received, and the number of days on which the storms reported showed distinct movement: —

Month.	Days on which reports were received.	Days on which storms showed movement.
January	1	0
February	3	1
March	4	2
April	4	2
May	12	5
June	18	6
July	26	11
August	17	6
September	9	4
October	3	0
November	4	4
December	1	0
Totals	102	41

It appears from this table that May, June, July, and August were the months in which thunder was most frequently heard, and that July was the month of most frequent distinct thunderstorms. The small number of observers from January to May and from October to December makes any comparison for these months unreliable. The time of occurrence was, in the majority of cases, in the afternoon, and the hours of maximum frequency were 5 to 7 P. M. The average rate of movement of all the storms throughout the year was about thirty-five miles an hour. The small number of records has, in many cases, made accurate charting impossible, but this determination of the velocity may be considered fairly accurate. It is noticeable that the lowest velocity recorded was in the case of the storm of July 18, which occurred under anticyclonic conditions, the rate being eighteen miles an hour.

During June, fourteen storms with distinct progression were reported. In ten cases the cyclonic centre was between sixty-seven degrees and seventy-two degrees west longitude, north of the

St. Lawrence; three storms occurred with no distinct centre of low pressure, and one occurred under anticyclonic conditions. In order to see whether or not there was any characteristic arrangement of isobars in connection with cyclonic areas in Canada which brought thunderstorms to New England in this month, a composite portrait was drawn of the isobars at 7 A. M. on the days when storms occurred in the southern quadrant of cyclonic areas, the maps used as a basis being the Washington morning weather maps. The only relation that could be made out was on June 7 and 25, each of which showed a circular low pressure area over the lower Lakes, a high area over Nova Scotia, and isobars running north and south over New England. The next step was a comparison of weather conditions at 7 A. M. on the days which brought thunder storms, with the conditions on those days which had similar arrangements of isobars and brought no storms. The results are not very clear, but it seems from this tabulation that the days which brought storms had, as a rule, stronger gradients than those which did not produce storms. It is a noticeable fact that in several of the latter cases the cyclonic area was closely followed by a high area over the Lakes, or south of them, which, moving to the east, came over New England during the day, bringing anticyclonic conditions In all the cases of this kind, the pressure over the district at 7 A. M. of the following day was about thirty inches or over.

After taking out the maps of days when storms occurred, and of those days when apparently similar conditions brought no storms, fifteen maps were left, ten of which were distinguished by barometer over thirty inches, weak gradients, and generally light winds and fair weather, and on seven of these days no thunder was heard. This shows clearly that anticyclonic conditions are unfavorable for the production of thunderstorms. Of the remaining five days, three were characterized by anticyclonic conditions, but the pressure was slightly below the normal; the other two were cloudy, under the influence of cyclonic areas on the middle Atlantic coast and off Nova Scotia. The last step in the investigation was the examination of the thunderstorm records in the Monthly Weather Review of the Signal Service, for the purpose of determining whether or not Ohio, Pennsylvania, and New York had storms previous to the occurrence of the New England storms; for, in

this way, prediction might be possible for New England. The data given in the Review are insufficient for this study, but Prof. Hazen has found in his work that the series of storms during the month evidently progressed from west to east, across the country. For instance, New England had a storm on the 10th, Ohio and neighboring States had storms on the 9th, and Dakota, Iowa, and Nebraska on the 6th. In the same way, the New England storm on the 17th was preceded by storms in Ohio on the 16th, and in Iowa on the 14th; and the New England storms of the 25th by storms in Ohio on the 24th, and Dakota, Iowa, and Nebraska on the 22d.

During July, twenty-two well-defined progressive storms occurred. The locus of most of the cyclonic centres, in connection with which thunder storms occurred, was between sixty-two degrees and seventy-two degrees west longitude, north of New England, the centre being within these limits in fourteen of the twenty-two cases. In three cases the storms were practically at the centre of low pressure; in two they occurred under anticyclonic conditions, and in one case the cyclonic centre was over the Lakes. A similar plan to that used in the preceding month was adopted in July, August, and September also. The composite portrait of the isobars at 7 A. M. on the days when storms occurred in the southern quadrant of a cyclonic area showed no system beyond the general gradient to northeast, north, or northwest. The attempt to correlate certain kinds of weather with the occurrence of thunderstorms was also unsuccessful. The 7 A. M. maps of those days on which thunderstorms occurred were compared with the maps of those days when cyclonic centres occupied similar positions and no distinct storms occurred. The height of the barometer (shown by the lowest isobar), the strength of the gradients, the temperature, the rainfall, the direction and force of the wind, and state of the sky were noted in this connection. Eight cases were found of each kind, and there was apparently nothing to distinguish the weather maps which belonged to thunderstorm days from those which belonged to days of no storms. Of the days which had similar conditions of weather and pressure to those which distinguished thunderstorm days, three had no reports of thunder or rain, and five brought scattered reports only. After taking out the maps of days when distinct storms occurred, and also of

days when the cyclonic centres were north of New England and no distinct storms were noted, there were left thirteen maps. On eight of these the pressure over New England was shown to have been normal or above normal, with weak gradients. The last step in the investigation of the storms of July was again the same as in the case of June, viz., to see whether our local disturbances were not preceded by similar disturbances farther west. Through the kindness of the Chief of the Weather Bureau, the original records of the volunteer observers in Ohio, Pennsylvania, and New York have been rendered accessible as a further aid in the study. New York and Pennsylvania had so few observers in July that their records are of little value. The records from Ohio, however, show that the 13th, 14th, 15th, 17th, 26th, and 30th were days of extended thunder storms, and it will be noted that New England had well-marked storms on the 14th, 15th, 16th, 18th, 27th, and 31st, *i. e.*, on all days following those on which Ohio sent the greatest number of records. The New England storm of the 14th was preceded by storms in Pennsylvania and New York on the night of the 13th and 14th.

During August, nine storms showing distinct movement occurred, of which number six came when the cyclonic centre was on or north of the St. Lawrence, between sixty-seven degrees and seventy-two degrees west longitude, *i. e.*, roughly between Quebec and Father Point, one when the centre was northeast of Lake Ontario, one when it was over the Gulf of St. Lawrence, and one under anticyclonic conditions. The composite portrait of isobars again showed no definite system, nor was any relation seen between the weather conditions on thunderstorm days and those on days when similar pressure distribution brought no storms. Again, as in the other cases, taking out the two sets of maps just mentioned, nineteen maps were left. Of these, twelve were marked by pressure thirty inches or over, weak gradients, and generally clear or fair weather. Ohio sent the greatest number of reports on the 1st, 11th, 13th, 14th, 16th, and 22d. New England had distinct storms on the following days in two cases only. The results of foreign studies of thunder storms and of some of the studies in this country, have shown that in many cases such storms occur in connection with a tongue of high pressure projecting into the area of low pressure in the southern quadrant of these areas. The maps have been ex-

amined with a view to determining whether or not such a result can be made out for New England, but, as far as the isobars drawn on these maps are concerned, no result has been reached. A number of cases have been found where such tongues did exist, but they did not mark thunderstorm days as distinguished from days of no storms.

During September, six distinct storms were noted, all of which occurred with the cyclonic centre north of New England, between sixty-seven and seventy-two degrees west longitude; in four cases the centre was south of the St. Lawrence.

The study of the records of 1886 has brought out again very clearly the main facts in connection with our thunderstorms, — the rise of the clouds in the west, the squall-wind in front, the sudden and usually short rain, the cooling after the shower, the rapid clearing off, etc. Most of the observers send but brief notes; many have, however, added to our knowledge of these storms by intelligent and pointed records of various features of interest noticed in connection with them. The growth and movement of the clouds is a point which but few observers note at all, and yet it is of great value in any such study as this. Such a record as the following, for instance (from Longmeadow, Mass., July 29), is of much value. Speaking of the advance of the squall-cloud, the observer says: "Behind it the rain was falling in a smooth gray sheet; there were cumulus tops along on the upper side of the squall-cloud. At 3.30 the squall-cloud was overhead, and seemed much wider than at 3.15; the motions in the lower part of it were now quite plain; there seemed to be ragged pieces of cloud forming beneath and rising rapidly up into the mass; there was also a general stirring around of the masses this way and that. A strong northwest breeze struck here at the same time the squall-cloud was overhead." One of the features most often noted in the reports is the dividing of the storm as it reached the observer; in fact, there was hardly a thunderstorm all the summer which did not seem to divide at one or more stations. Although the records of this occurrence are quite numerous, it is impossible to make any definite statement with regard to the fact. It is known that these storms often vary in intensity in different parts of their course, and when an observer happens to be in one of these regions of less rainfall he will probably say that the

storm divided, leaving him in the middle of two districts of heavy rainfall. An interesting point in this connection is noted on July 18, when four stations in a southwest and northeast line, the direction of the storm's advance, reported a dividing of the clouds. This seems to show that such breaks may retain their position in the mass of the moving storm, and may travel for some distance with it; in this case the distance was fifty miles. Further and fuller records are needed to determine this point. In this connection, the record from Newburyport on July 30 is interesting. The observer says that the storm seemed to travel in two sections, one section with heavy thunder and heavy rain, and the other with heavier thunder and less rain, but remarks that probably there was no space between the sections, a fresh wind then prevailing very likely bringing some of the rain from the more distant section. On Aug. 3, Mr. Clayton, of Blue Hill, saw a distinct gap in the approaching storm, which seemed free from rainfall, though it was apparently raining heavily on each side. The gap gradually closed up, and the rain advanced with a continuous front.

The influence of the tides on the direction of the storms is brought out in several reports, — notably on July 22 and on Aug. 6, when two observers declare that with a tide running east the thunderstorms move east, and with a tide running west the storms move west. The belief that the rivers and the topography of the land have an influence on the direction of movement of thunderstorms is widespread, and many records speak of such instances. South Orleans, Mass., for instance, on July 30, says that that district has materially less rainfall than the other parts of the Cape, a fact which is accounted for by the "configuration of the physical features." In spite of this very general opinion, it seems difficult to believe that such large disturbances as thunderstorms, whose convectional ascent is high enough to bring snow and hail in summer, can be affected by slight depressions and elevations of the earth's surface.

The results of the investigation of 1886, while in many ways rather unsatisfactory, are still worthy of note. The main results of the study of the previous year have been again emphasized, — the general features, the excess in the later afternoon hours, the fact that most of our New England storms come to us ready-made from the west of our district, and that they are not

distributed evenly through the summer, but appear in considerable numbers for a few days and then disappear for a time. In regard to the dependence of our thunderstorms on the larger atmospheric disturbances, or cyclonic storms, the results of 1886 in New England tend to show that this dependence, although marked, is not so striking or so definite as many of the foreign results have shown it to be in Europe. Over sixty per cent of the thunderstorms of this year occurred in the southern or southwestern quadrant of cyclonic areas, but there has been found no means of distinguishing those days on which thunderstorms occurred from those days when well-developed low-pressure centres passed north of New England without bringing local storms. Some of the best-developed storms of the year occurred under distinctly anticyclonic conditions. The effort that has been made in this work to come to some definite basis for the prediction of thunderstorms in New England has therefore not been successful. It is hoped, however, that the results which have been reached will not be a useless contribution to the subject of thunderstorms in general.

HARVARD COLLEGE, April, 1892.

THE STORM OF MARCH 1 TO 4, 1892.

J. WARREN SMITH.

The storm was preceded by nearly two weeks of cloudy, threatening weather along the New England coast, and for nearly one week over the interior and western sections as well. This weather may be explained in most part by the positions of the areas of high and low pressure during the time. From the 19th to 24th an anticyclone hung over the St. Lawrence valley and northern New England, and during that time a cyclone of slight energy passed off the Middle Atlantic coast. The result was continuous northerly winds and clouds along the coast. On the 25th, a cyclone — the sixth of the month — moved from the Mississippi valley over the Lakes and down the St. Lawrence valley with slight energy, but with moderate southerly winds and light occasional precipitation. It was quickly followed, on the 26th, by another anticyclone, which spread from Manitoba

eastward over Canada, and gave a continuation of the northeast winds and threatening weather.

On the last day of the month, while the anticyclone lay over the Gulf of St. Lawrence, a cyclone reached the Middle Atlantic coast, having come from the northwest to the Lower Mississippi valley, then up the Ohio River, and across to northern Virginia. On April 1 the cyclone moved northerly to the New Jersey coast, and then turned eastward onto the Atlantic. Its course from this point is traced on the Pilot Chart of the North Atlantic Ocean for April, issued by the United States Hydrographic Office, as follows: From April 1 to 2 the centre had moved first northeast, then southeast to a point about fifty miles off the Maryland coast; it then moved northeasterly, and at noon of the 3d was far off New York; on the 4th it was moving slowly and more nearly east; from that point it turned more toward the north, passed around Sable Island, and curved to the northwest into the Lower St. Lawrence Gulf on the 5th. It continued its movement westerly, curving toward the southwest, and at noon of the 6th was in the Bay of Fundy, having moved over very little space. It then curved toward the south, east, and finally northeast, passed across its former path, and at noon of the 7th was central over Newfoundland, moving northerly. Its course beyond that point cannot be determined.

The precipitation began in southwestern New York on the evening of Feb. 29, and on the southern New England coast in southwestern Connecticut soon after midnight of April 1. It reached Rhode Island about 6 A. M., and stations on the Cape at between 8 and 9 A. M. At Nantucket, Mass., it began at 10.20 and at Boston at 11 A. M. In southern Vermont snow began between 5 and 6 P. M., and in central New Hampshire on the early morning of the 2d. In Maine, no precipitation fell until the early morning of the 3d.

There seemed to be two distinct storms; the first beginning on the morning of the 1st and ending during the night, and the other beginning during the night of the 2d. It is evident that the former did not reach Maine, and that the latter was not felt in the more western sections. In southern Vermont and western Massachusetts only the first storm was experienced to any extent, many stations reporting no snow after the 2d. While this space between the two storms was well marked at many

stations, there being a complete cessation of the storm on the 2d, at others it was continuous, and the storm was nearly as hard on the 2d as on the other dates. As the two storms were caused by the same cyclone, and because the precipitation was nearly continuous at several stations, no effort has been made to separate them, and what is given below includes both storms.

By far the most severe part of the storm was on the Massachusetts coast and at Block Island. Over twelve inches of snow fell at many places, and this was piled into immense drifts by the high winds. At Block Island the snow was damp and heavy on the 1st. At 3 P. M. the wind attained a velocity of seventy-seven miles per hour. During the night the snow became dry, and on the 2d it was still falling heavily, with a wind velocity of fifty or sixty miles per hour. The maximum reached sixty-six miles on this date. Dry snow continued on the 3d, and on this day the wind reached sixty miles per hour. Very high tides were experienced here, but no damage was done.

At Nantucket, Mass., it was the heaviest storm for years. The wind blew at the rate of fifty-two miles per hour. Here the snow ended during the night of the 2d, and began again at 8.47 A. M. of the 3d. The high wind continued, and drifts were formed on all sides from five to eight feet in height.

At Provincetown the snow was preceded by little rain, and was continuous until the night of the 3d. It was what is there called a "smothering nor' easter," and caused much suffering among the life-saving crews that patrolled the beach. It caused the cessation of all outside business, as seeing and breathing out of doors were also impossible. Many vessels came in badly used up, and one train was seventy-two hours late. Many drifts were seven feet in height.

At Hyannis the precipitation on the 1st came in the form of rain. It changed to snow during the night, and continued until 10 A. M. of the 2d. It held up most of the day but began again during the night, and was very heavy on the 3d. The snow was dry, and drifts were formed from three to seven feet in height. All streets running north and south were blocked. The frozen snow on the roofs of the houses protected them from a large fire that occurred there; a dozen sets of buildings were showered with burning coals and firebrands, and but for the covering of snow would have been consumed. The trains going

toward the Cape could not get through at all on the afternoon of the 3d.

At Cotuit it was the most severe storm in twelve years. Rain began on the morning of the 1st and changed to sleet during the day. It turned to snow at 10 P. M. and continued till next morning very damp. It held up during the 2d, but began again in the late afternoon. Roads were badly drifted but no damage was reported.

At Bristol, R. I., the wind was not five points from the northeast from Feb. 19 to April 4, and there were only a few hours of sunshine during all that time. At this station, on the morning of the 2d, at 7 A. M., the wind suddenly shifted to north from north-northeast, and increased in force, when the temperature fell from twenty-seven degrees to eighteen degrees in one and one half hours.

At Providence, R. I., the precipitation on the 1st was in the form of snow, but very damp, and almost rain at times. At night the temperature fell below freezing and snow came. It was badly drifted on the 3d on the ice and crust. The temperature fell from thirty-one degrees at 10 P. M. of 1st to fifteen degrees at 8 A. M. of 2d, and then remained almost stationary for twenty-four hours, after which it rose.

Farther down the coast, toward New York, the storm was less severe. At Norwalk, Conn., no snow fell on the 3d, while up toward Boston the storm of the 3d was of greater energy than that of the 1st. At Taunton and Middleboro the snow melted as fast as it came, on the 1st, but became dry on the 2d and 3d, being practically continuous. It was the most severe storm for several years. At Taunton the wind was not high until the evening of the 1st. Drifts from six to ten feet in height were formed in the city and many suburbarn roads were impassable. Teams were stalled and in the city the snow-plough could not be used and men with shovels had to clear the streets. Milkmen and butchers did not reach their customers in many cases until noon and in others not at all.

At Plymouth the snow was driven with such velociety and the air was so filled with it that horses could scarcely get about. Drifts from eight to ten feet in depth were formed. It was the hardest storm since March, 1888, and surpassed that in having a higher wind velocity and lasting longer. On the morning of

the 3d two men while walking on the track were struck by the snow plough and fatally injured: the snow was so thick that the engineer could not see them. Several families went hungry for a day or two, but nothing more serious occurred.

The Scituate, Nantasket, and Hull beaches were badly washed, but no serious damage was done. On the 3d the express teams did not attempt to drive to Boston from Quincy, and linemen experienced difficulty in getting teams to get out to repair their wires, as the roads were so badly drifted. Several pilots could not be taken off the outgoing steamers in the lower harbor and were compelled to take a trip across the Atlantic.

At Blue Hill, Mass., the greatest daily snowfall was on the 2d and the greatest hourly fall was at 5 A. M. on that day. The maximum wind on the 1st was sixty-three miles per hour at 8.30 P. M.; on the 2d, fifty-one miles at 11.30 A. M., and on the 3d, forty-five miles at 7.30 A. M. The temperature ranged from thirty-one degrees to twenty-eight degrees on the 1st, twenty-eight degrees to twelve degrees on the 2d, and twelve degrees to twenty-two degrees on the 3d. The pressure was normal and nearly stationary on the 1st and 2d, and falling slightly on the 3d.

Along the beach to the north of Boston considerable damage was done. The light-house keeper at Egg Rock off Nahant reports it to be the hardest storm in his experience. He states that the lobster fishermen who fish within three miles of the island lost upwards of five hundred dollars' worth of nets and fishing gear. All along the Lynn and Swampscott beaches the spiles and planking put up to protect the property on the water front were washed out, and in many places even the heavy stone fronts were carried away.

At Newburyport the snow was dry throughout the storm, and was much drifted. The life-saving crew along that beach report no harder time since the winter of 1888. The outer-range light on Salisbury Beach Point was in great danger; the sand was washed out to within a few feet of the light and it was in imminent danger of going over. At Plum Island the whole beach was changed; where there was formerly an even plain hills fifteen feet high were formed, and where there were hills valleys can now be seen.

At Newton, N. H., the greater part of the snow came on the 3d. Drifts formed there from three to six feet high and made both sleighing and wheeling impossible.

Farther down, on the Maine coast, the storm was quite severe, but came on the 3d, although high winds and threatening weather occurred the 1st and 2d. At Belfast the fall was dry and heavy all day. It drifted badly, and the mean temperature for the day was about fourteen degrees. It was the hardest storm of the season.

At Calais, Me., it was the hardest storm for years.

At Houlton, Me., it was not specially severe, but it did not end until the morning of the 4th, and another inch of snow fell on the evening of the 4th.

At St. John, N. B., the snow ended on the morning of the 4th, but it was followed on the 4th, 5th, and 6th by showers of sleet and hail. At that station the barometer began to fall at 6 A. M. of the 3d (twenty-four hours before snow began) and continued to drop until 8 A. M. of the 6th, when the corrected reading was 29.08 inches. The sleet and hail was without doubt caused by the storm when it was recurving into the Bay of Fundy. The pressure at the centre of the storm at that time must have been considerably below twenty-nine inches. To show how much less severe the storm was farther away from the coast, we will give a few extracts from reports at the different stations:—

Colchester, Conn., "Snow badly drifted. The engine on the Air Line was thrown from track in a cut near here." — Canton, Conn., "Wind not severe as we frequently have it. Snow not drifted enough to interfere with railroading or private conveyance."—Storrs, Conn., "Snow all day of 1st, just squalls on 2d and 3d."— Thompson, Conn., "Storm not specially severe."— Leicester, Mass., "The highest wind was on the 1st and then gradually went down to the end of the storm."— Springfield, Mass., "There was about two inches on the 1st, and light snows on the 2d and 3d." — Turner's Falls, Mass., "Snow-storm very light and with no serious results." — Monroe, Mass., "Four inches on the 1st and squalls on the 2d; slightly drifted." — Wells, Vt., "All but one inch fell on the 1st; not severe." — Brattleboro, Vt., "Snow came mostly in squalls."— Peterboro, N. H., "Nothing remarkable about the storm here." — Concord, N. H., "There was nothing remarkable about the snow-storm in this vicinity; about four inches on the 1st, cloudy weather on the 2d, and four inches on the 3d. The wind was light, and it did not drift badly."— Lakeport, N. H., "Storm light." — Plymouth, N. H., "Snow squalls

only on the 2d. Fifteen miles southwest of here three or four inches fell during the night of the 1st, while eighteen miles southeast of here some eight inches fell and drifted badly." — Bethel, Me., "Storm light." — Kent's Hill, Me., "Storm was quite ordinary." — Lewiston, Me., "Little snow on the 2d." — Berlin, Mills, N. H., "One inch on afternoon of 3d." — Stratford, N. H., "Just a squall on the 1st." — North Conway, N. H., "Just a squall on the 1st." — Enosburgh Falls, Vt., "Indications of snow on the 3d but no precipitation." — Lunenburgh, Vt., "No storm; no wind over twenty miles per hour." — Burlington, Vt., "No precipitation since Feb. 20 and no signs of any."

It has been suggested that as a storm has occurred along our coast for each of the last three years during the first three days of March, this time might be a period for such storms, and on investigating it is found that since 1872 a storm has occurred between March 1 to 4 on twelve of the years. In 1888 the storm passed across New England, but in every other case it came up the coast and gave heavy snows and high winds along the New England coast. On one year when no storm came up our coast (1886) one had just passed across to the north and terrific northwest gales occurred over New England and the Middle Atlantic States. It might be an interesting work to investigate the history of each of these storms from beginning to end as well as to study the meteorological conditions obtaining on those years when no storm has occurred.

U. S. Weather Bureau, Boston, April, 1892.

CURRENT NOTES.

ROYAL METEOROLOGICAL SOCIETY.

THE usual monthly meeting of this Society was held on Wednesday evening, Feb. 17, at the Institution of Civil Engineers, 25 Great George Street, Westminster; Dr. C. Theodore Williams, president, in the chair.

Capt. D. S. Cromarty, Mr. R. Godfrey, Assoc. M. Inst. C. E., Mr. C. Shapley, Mr. E. J. Smith, Mr. E. K. Spiegelhalter, Rev. H. Stewart, and Rev. W. E. Stewart, M. A., were elected Fellows of the Society.

The following papers were read: —

"The Untenability of an Atmospheric Hypothesis of Epidemics," by the Hon. Rollo Russell, M. A., F. R. Met. Soc. The author is of opinion that no kind of epidemic or plague is conveyed by the general atmosphere, but that all epidemics are caused by human conditions and communications capable of control. In this paper he investigates the manner of the propagation of influenza, and gives the dates of the outbreaks in 1890 at a large number of islands and other places in various parts of the world. Mr. Russell says that there is no definite or known atmospheric quality or movement on which the hypothesis of atmospheric conveyance can rest, and when closely approached it is found to be no more available than a phantom. Neither lower nor upper currents have ever taken a year to cross Europe from east to west, or adjusted their progress to the varying rate of human intercourse. Like other maladies of high infective capacity, influenza has spread most easily, other things being equal, in cold calm weather, when ventilation in houses and railway cars is at a minimum, and when perhaps the breathing organs are most open to attack. But large and rapid communications seem to be of much more importance than mere climatic conditions. Across frozen and snow-covered countries and tropical regions it is conveyed at a speed corresponding not with the movements of the atmosphere but with the movements of population and merchandise. Its indifference to soil and air, apart from human habits depending on these, seems to eliminate all considerations of outside natural surroundings, and to leave only personal infectiveness, with all which this implies of subtle transmission, to account for its propagation.

"The Origin of Influenza Epidemics," by Mr. H. Harries, F. R. Met. Soc. The author has made an investigation into the facts connected with the great eruption of Krakatoa, in 1883, and the atmospheric phenomena which were the direct outcome of that catastrophe. He has came to the conclusion that the dust derived from the interior of the earth may be considered the principal factor concerned in the propagation of the recent influenza

epidemics, and that, as this volcanic dust invaded the lower levels of the atmosphere, so a peculiar form of sickness assailed man and beast.

"Report on the Phenological Observations for 1891," by Mr. E. Mawley, F. R. Met. Soc. This report differs in many respects from the previous reports on the same subject. Among other changes, the number of plants, etc., selected for observation has been greatly reduced, while the number of observers has considerably increased. The winter of 1890–91 proved in England very destructive to the root crops, as well as to green vegetables and tender shrubs. Birds, also, suffered severely. In Scotland and Ireland, however, there was scarcely any severe weather until March. The flowering of wild plants was greatly retarded by cold in the spring, but during the summer the departures from the average were not so great. The harvest was late and its ingathering much interfered with by stormy weather.

"Note on a Lightning Discharge at Thornbury, Gloucestershire, July 22, 1891," by Dr. E. H. Cook.

At the meeting of this Society on March 16th, Dr. C. Theodore Williams, the president, delivered an address on the "Value of Meteorological Instruments in the Selection of Health Resorts." He drew attention to thermometers, maximum and minimum, as the foundation-stone on which medical climatology rests, and instanced effects of extreme cold or of heat on the human organism. The direct rays of the sun are of the greatest importance, and in health resorts should be utilized to the full; in fact, only climates where, during the winter months, even a delicate person can lie or sit for several hours a day basking in the sunshine are to be recommended, for most complaints, and the various forms of sunshine-recorders are used to aid the medical adviser in choice of such health stations. After referring to the value of rain-gauges, hygrometers, and barometers, Dr. Williams stated that many health resorts owe their reputation almost solely to their shelter from cold winds; for instance the advantage in climate which Hyères and Mentone enjoy over Marseilles is chiefly due to their being more sheltered from the Mistral, or northwest wind, the scourge of the lower valley of the Rhone from Valence to Avignon. He went on to describe the climate of the Riviera, illustrating it by lantern slides from recent photographs, including views of Hyères, Costabella, Cannes, Nice, Mentone, San Remo, etc., and he showed the three principal causes of the warm winter of this region to be (1) the southern latitude; (2) the protection from cold winds by mountain ranges, and (3) the equalizing and warming influence of the Mediterranean Sea, which, being practically tideless, is always equally potent, not varying with hour and season. Dr. Williams mentioned the weak points of the South of France climate, with its blustering Mistral, its occasional cold Bise, and its moist Sirocco wind, but summed up the Riviera winter climate as being, as a whole, clear, bright, and dry, with fog and mist practically unknown, with a winter temperature of eight degrees to ten degrees higher than England, though subject to considerable nocturnal radiation, with about half the number of rainy days, and four or five times the number of bright ones which we can boast of, with cold winds and cold weather, without which it would lose its health-giving effect.

After the delivery of this address the meeting was adjourned, in order to allow the Fellows and their friends an opportunity to inspect the exhibition of instruments relating to climatology which had been arranged in the rooms of the Institution of Civil Engineers, 25 Great George Street. The meteorological office showed a set of instruments necessary for the equipment of a climatological station, viz., Stevenson thermometer screen, fitted with dry bulb, wet bulb, maximum and minimum thermometers, and also a rain-gauge. Thermometers were also shown for ascertaining the temperature on the ground, under the ground, and at a distance, as well as for recording temperature continuously. Various forms of sunshine recorders were exhibited, as well as a number of actinometers and solar-radiation instruments, for ascertaining the heating effect of the solar rays. The exhibition included a large and interesting collection of hygrometers, also several rain-gauges and other instruments. Among the curiosities was a piece of plate-glass which was "starred" during a thunderstorm on Aug. 21, 1879. This was not broken, but it has a number of wavy, hair-like lines. The exhibition contained a large number of beautiful photographs of clouds, lightning and snow scenes, as well as of the damage done by the destructive tornado at Lawrence, Mass., U. S. A.

THE WEATHER BUREAU IN ITS RELATION TO AGRICULTURE.

At a meeting of the Massachusetts Horticultural Society held in Boston, March 26, Mr. J. Warren Smith, of the United States Weather Bureau, read a paper on "The Relation of the Work of the Weather Bureau to Agriculture," the substance of which was as follows: —

This department of the United States service was established by the act of Congress of Feb. 9, 1870, and its care and supervision placed in the hands of Brig.-Gen. Albert J. Meyer, the chief signal officer of the United States Army. Hence the name Signal Service by which this department has been known until recently. It was strictly military in its organization, all its employees being officers and enlisted men of the United States Army. The act establishing this service was the first governmental legislation looking to a national Weather Bureau; its first work the beginning of official effort to solve the problem of American weather. Its duties, as set forth in the act establishing the service, were "to take and record meteorological observations, and to report, and give notice, by electric telegraph of the approach and the force of storms, for the benefit of commerce and agriculture."

The actual work began Nov. 1, 1879, with the 7.35 A. M. observations, taken synchronously, at twenty-four stations in various parts of the whole country. The elements of these observations were: Temperature and pressure of the air; the percentage of moisture or relative humidity; the temperature of the dew-point; direction, force, and velocity of the wind; kinds and amount of clouds; amount of precipitation — rain or melted snow — in inches and hundredths; character of the sky, and the state of the weather.

In addition to these a record of all special phenomena, such as auroras, halos, thunderstorms, tornadoes, water-spouts, earthquakes, etc. These data were telegraphed to Washington, the central station, at stated times, and from there transmitted in the same manner to offices located at the commercial centres of the entire country, from which the information was disseminated through the daily papers, by the public display of bulletins and other methods.

Upon the foundation thus laid has been erected what is now the finest weather service in the world. Nearly all civilized countries now have weather services, of varying extent and value, but, excepting the study of some special phenomena by some of them, ours is far ahead. Our system of observation, collecting data, and putting the information before the public is incomparable.

Soon after this work was commenced the public demanded deductions looking to the pre-announcement of coming weather conditions and changes; approach and force of storms; of cold waves, early frosts and their probable severity: freshets and floods. The chief called to his aid our learned meteorologists and scientists, and on Feb. 19, 1871, issued the first bulletin of "probabilities," since called "indications" and now "forecasts."

Thus far the labors of the service were chiefly in the interest of agriculture. The next step was the display of storm signals at stations on the seaboard, the Gulf and the Great Lakes, by means of large flags by day, and colored lights by night. At first twenty such stations were established; now a chain of them extends from the Rio Grande, Gulf of Mexico, to Eastport, Me., throughout the Great Lakes, and along the Pacific coast, all in the interest of commerce. The observing stations have increased to over one hundred and fifty, nearly all being furnished with continuous self-recording instruments. In addition, over two thousand volunteer observers are at work, under the direction of the Government. There is a department for the study of cold waves, of the approach of which warnings can be given from twelve to thirty-six hours before they reach us, by a system for displaying this information by flags and mill whistles, for the benefit of growers and shippers of fruits and other perishable goods; and also forecasts of daily weather from thirty-six to forty hours in advance. The great territory of the United States has been divided into districts, and, by making a special study of each, the "forecasts" are made more definite and exact for each of them, thus more effectually promoting the interests of the farmers therein. In the cotton belt a special system of rainfall and temperature observations has been adopted for the benefit of the planter and dealer. So in the great strawberry growing region of New Jersey and adjacent territory, foreknowledge of weather and temperature is of the highest importance, and is watched as closely by dealers in Boston as by the Jersey farmers. The flood-warnings of the great valleys of the Mississippi and tributaries have been of incalculable value. Through the observations of this service, it has become known that hundreds of square miles of land in the western part of our country which a few years ago were considered little better than a desert do have seasonable rains, and

therefore are valuable for cultivation. Observations are utilized in the study of our climate in relation to health. The daily forecasts are depended on by almost every branch of industry. Scientists have studied the data accumulated, to ascertain if our climate is really changing, but little evidence in favor of that idea has been secured.

Observations are made at all the regular stations twice each day, at eight o'clock A. M. and P. M., and the result telegraphed to Washington; there charts are made for the whole country. A part of the data is telegraphed to central stations all over the country, where maps are made for their immediate vicinity. On these maps are expressed by figures and symbols the exact weather conditions at each station; then, by drawing a system of lines, isobars and isotherms, we indicate the different weather areas, or waves of good and bad weather; then, by knowing the laws of storms, one can tell, by just a glance at the map, what weather conditions we are liable to have to-night or to-morrow, and, in some cases, several days to come. The issue of these maps, which are sent to many of the post-offices in the district, is one of the most important duties of our local offices.

The Boston office is the birthplace of this map, and it is here that most of the improvements have been made in the appearance of the map, and in the system of printing a large number of copies in a short time. The result of observations taken on the Pacific coast at eight o'clock this morning were being entered on the chart here at 9.30 A. M., together with those from all over the country; and by noon, or a little later, the eight hundred and fifty copies of the map issued here daily will be ready for the mail. The earth's atmosphere is constantly in motion; not only near the surface but throughout its extent. The waves of dense and of rarified air are indicated by the barometer. Areas of low barometric pressure have clouds and possibly rain, with warm weather, while areas of high pressure have clear, cold weather. Another law is that the wind always blows from an area of fair weather — high pressure — toward a stormy or cloudy area, where low barometric pressure prevails. The velocity of the wind depends on the gradient, or greater or less difference in the pressure or density of the air of the two areas involved.

Some special lines of work to be developed are: Collecting accurate meteorological records for climatic investigation in relation to the growth of crops and to the health conditions, the collection of reliable crop information and data of the weather affecting crops, and the issue of weekly crop bulletins during the summer season; more special and specific weather forecasts by the local forecast officials, and a wider dissemination of these forecasts in the agricultural districts; also the extension of frost-warning systems throughout the fruit, tobacco, and cranberry sections.

We often speak of the climate of a State or of a country; it is found that not only does the climate of countries and States differ, but that each town and each man's farm has a climate peculiar to itself; also that the study of the climate of one farm and its influence on the growing crops will not apply to an adjoining farm. Therefore, while we cannot hope to establish a station for studying the climate on each man's farm, there is no question

that each farmer would be greatly benefited if he should pay more attention to the study of the climate and its relation to his several crops.

During the growing season a large number of correspondents are enlisted all over the country to gather and transmit reliable information on the progress of the crops, and effect of the weather upon them. This information condensed is issued in weekly bulletins, and by following these bulletins one can make a correct estimate on the conditions of any crop in the whole country, or in any state or county. This is one of the most practical features of the Weather Bureau work, and we are now enlisting the voluntary services of persons all over New England for the coming summer season, that this department of our work may be done more effectively, because more locally applicable.

Thus it will be seen that the entire work of the Weather Bureau is of most interest and value to the industries of the country, and to its commerce, which largely grows out of those industries. Agriculture is the chief industry, therefore the Weather Bureau was, on July 1, 1891, transferred from the War Department, to become a division of the United States Department of Agriculture. This change places the affairs in the efficient hands of Gen. Rusk, secretary of agriculture, and Prof. M. W. Harrington, our new chief. Upon the completion of this transfer, twenty local forecast officials were appointed, and such improvements in the work secured that, beginning Jan. 1, 1892, the forecasts that are received in the early morning cover the probable weather until midnight, and those received about noon indicate the weather until 8 P. M. of the following day. This increased advance must prove of great value to all agricultural and horticultural interests both in the growing of crops and trade in the products.

THE NEW ENGLAND METEOROLOGICAL SOCIETY.

The New England Meteorological Society was organized in June, 1884, in order to advance the science of meteorology and to promote a popular interest in its study. Since its organization the Society has, through its council, carried on three classes of work: (1) The regular observations, taken by its members and by other volunteers, and including the various weather elements, especially precipitation and temperature. The results of these observations have been published in the monthly bulletin of the society, and in its annual summary. (2) Special investigations, the results of which have been published from time to time. Among these investigations may be mentioned the study of thunderstorms in New England during 1885, a report on which was printed in the Proceedings of the American Academy (Boston) for 1886, and a study of the sea-breeze along the New England coast, the results of which were published in the Annals of the Astronomical Observatory of Harvard College for 1890. Both of these reports were valuable additions to the subjects with which they dealt. The thunderstorms of 1886 and 1887 will form the subject of another report soon to be issued in the Annals of the Harvard College Observatory. (3) The

holding of stated meetings, at which papers on various matters of interest have been read, these papers having been subsequently printed in this JOURNAL.

That part of the work of the society which deals with the matter of current observation has been so extensive that it could not have been carried on at all without the generous assistance of the Signal Service, and of its successor, the Weather Bureau of the Department of Agriculture. Both of these services have given the Society constant help, in the person of an assistant detailed to conduct this work under the direction of the Society, which has therefore acted as the local weather service in New England. The Chief of the Weather Bureau has recently submitted a plan to transfer the management of the current observations and the publication of the monthly bulletin to the Weather Bureau, for the formation of a New England Weather Service, under a director, as in the other states, and the council on March 17 voted to recommend to the Society that the proposed transfer be made. At a special meeting held on April 6 the Society voted that this transfer be made.

SOLAR ECLIPSES AND AIR PRESSURE.

Observations of air pressure during a total solar eclipse reveal an influence of the latter phenomenon on the former. In a recent number of the "Annalen der Hydrographie," Herr Steen studies the eclipse of Aug. 29, 1886, in this respect, using the records (at intervals of a quarter of an hour) of fourteen Norwegian ships between Panama and Madagascar, of which four were in the zone of totality, and at least four others quite close to it. Having first eliminated the daily period of air-pressure, he groups the observations of the ships, and forms means; and he finds both these and the individual records reveal two maxima of air pressure, separated by a minimum. In the totality zone the first maximum is thirty-five minutes, and the second, two hours and fifteen minutes, after the middle of the eclipse; in the partial zone, the first is twenty-five minutes before, and the second, one hour and forty minutes after, the middle. This double wave Herr Steen explains thus: During a solar eclipse day is changed to night for a short time, and the transition is much like the ordinary change from day to night in the tropics, where the twilight is but short. There the curve of air pressure has regularly a maximum about 10 P. M., some time after sunset, and a minimum about 4 A. M., shortly before sunrise; while a second maximum appears about 10 A. M. It is natural a total solar eclipse should act similarly. The displacement of the epochs of the air-pressure wave in the partial zone as compared with the zone of totality is more difficult to account for.— *Nature*;

Statistics of Lightning Strokes. — According to "Ciel et Terre," the number of strokes in Saxony for every million buildings was, on an average. 107, for the period 1859 to 1862; 161, from 1867–1870; 215, from 1875–1878, 318 from 1883–1884, 185 for 1888, and 621 for 1889. Prof. Karsten estimates the total annual loss due to lightning in Germany at six to eight

million marks. If the danger increases in the future in anything like the above ratio it will soon cause a loss of from twenty-five to thirty million marks.

Electricity and Clouds. — From simultaneous observations made at the observatory at Vesuvius and at the University of Naples (five hundred and eighty metres difference of elevation), it appears that in winter the electricity of the clouds is generally less than the values obtained at the University, whether clear or cloudy. When rain falls at the observatory there is noticed a strong positive indication, and conversely a strong negative value at the University. Conformably to the law announced in 1884 by Palimeri, from May to October the electricity is stronger at the observatory than the University, but when the observatory is wrapped in clouds the opposite condition prevails, the electricity being always stronger at the University than at Vesuvius.

Meteorological Work for Agricultural Stations. Under the above title, the Department of Agriculture has recently issued a pamphlet (Experiment Station Bulletin No. 10) by the Chief of the Weather Bureau, which was prepared at the request of numerous officers of the experiment stations and contains some valuable suggestions. While these agricultural institutions cannot, by reason of their situation in the country districts, become telegraphic centres for weather work, they may collect valuable data on such matters as the distribution of temperatures in the soil and air in connection with the animal and vegetable life, the changes of temperature with the hour of the day, or the topography, the occurrence of frosts, the distribution of moisture, radiation, precipitation, and in other cases where the data can be got together slowly and worked up later, as in thunderstorm, tornado, and hail-storm investigations. The vertical distribution of temperature is of great importance, especially in the case of frosts, where, as is well known, there is often a perfectly distinct dividing line between the frost-covered vegetation and that uninjured by the frost. The application of this sort of knowledge to the growing of plants in the most favorable situations is apparent, and the prediction of frosts by means of the psychrometer and the dew-point is also an important matter, and one not yet sufficiently accurately determined. Evaporation and the amount of the condensation and the precipitation of the atmosphere need much further study, and in this connection the effect of dust particles on the formation of fog and rain, so perseveringly worked out by Aitken, may well be investigated further. Chemical investigations into the composition of the air, which varies at different times, would be useful. The local prediction of thunderstorms, which have been found to move in a general easterly direction, can, by some further study, probably be brought to a high degree of accuracy, so that telegraphic and telephonic warnings may be sent out in advance of the storms.

This valuable and suggestive pamphlet closes with a list of the outfit needed in meteorological work of this kind, and also a list of the principal recent works on meteorology as well as of the principal periodicals bearing on the subject.

BIBLIOGRAPHICAL NOTES.

A NEW METEOROLOGICAL MAGAZINE.

*L'Atmosphere.** This small periodical made its first appearance Feb. 1, 1892. It is a monthly review of meteorological papers, and is published under the auspices of the Observatory de la Tour St. Jacques, in Paris. On the cover pages is a bibliography of meteorological papers of importance recently published, a feature that might perhaps be profitably imitated by all meteorological journals. This bibliography however is very far from being complete. With the exception of "Nature," no English periodical appears. The American Journal of Meteorology is also omitted in company with the German reviews. The contents of this first number are, a Description of the Halo seen at Paris Jan. 14, 1892, 9 to 10 P. M., by E. Renou; an interesting article on Cloud Observations, with new methods for determining their altitude, direction, and absolute velocity, by E. Prévot, chief of the Topographic Survey of France; Terrestrial Magnetism in 1892, by Th. Moureaux, and a paper on the Influence of Mountains on Climate, by G. Gandy. A "Current Notes" department contains many interesting and well-chosen items. The Observatory records for the month (January, 1892) are also given in detail. It may not be out of place to note that this Observatory began its regular meterological work last July; observations being made four times a day, the other hours being obtained by Richard self-registering instruments, checked of course by these eye readings. The instruments are: 1st floor, barometers and barographs, including standard barometer, mercurial register, metal barograph, and water barograph; electrometer, etc., in the pavilion, thermometers, wet and dry, maximum and minimum, thermograph, hygrograph, pluviometers, ozonometers, radiation thermometer, and ground thermometer (30 cms.); at top of the tower, thermometers as above, with registering rain-gauge, a Vaussenat snow-gauge, a Hervé Mangon pluvioscope, an Arago actinometer, a photographic sunshine recorder, a registering anemometer (both velocity and direction), an ozonograph, a radiation photometer, etc.

The work of the Observatory is intrusted to M. Joseph Jaubert, who, with M. Tavet, makes the observations. The special photographic service is under M. Edouard Grieshaler. Besides these the Observatory has the assistance of the following non-resident staff:—

Topography, Geodesy, etc., Prof. Prévot; Astronomy, Prof. Brunel;

* Paris. Libraire des Sciences Nat. Paul Klincksieck, 52 Rue des Ecoles.

Electricity and Optics, Prof. Hoornaert; Electricity, Prof. Avril; Photography, Mm. E. Cousin and Goddée.

M. Dr. Chassaings is chief of the Board of Directors.

The Observatory has also a physical laboratory.

" L' Atmosphere " is to appear regularly about the 10th of each month and each number will contain sixteen pages. A. M.

The Principal Recent Works on Meteorology.—The principal recent works on meteorology, aside from those published by the Weather Bureau, as given in a recent publication of the Department of Agriculture (" Meteorological Work for Agricultural Institutions "), are as follows : —

GREELY, American Weather, New York, 1888.

FERREL, Popular Treatise on the Winds, New York, 1889.

BLANFORD, Climates and Weather of India, London, 1889.

ABERCROMBY, Weather, London, 1888.

ABERCROMBY, Seas and Skies in many Latitudes, London, 1888.

SCOTT, Meteorology, London, 1883.

DAVIS, Whirlwinds, Cyclones, and Tornadoes, Boston, 1884.

HAZEN, Tornadoes, New York, 1890.

HAZEN, Meteorological Tables, Ann Arbor, 1890.

MARIE-DAVY, Météorologie générale, Paris, 1877.

HANN, Handbuch der Klimatologie, Stuttgart, 1883.

SPRUNG, Lehrbuch der Meteorologie, Hamburg, 1885.

VAN BEBBER, Ausübende Witterungskunde, Stuttgart, 1885.

GUNTHER, Meteorologie, München, 1889.

MOHN, Grundzüge der Meteorologie, Berlin, 1887.

WOEIKOF, Die Klimate der Erde, Jena, 1887.

MEYER, Meteorologische Beobachtungen, Berlin, 1891.

HOFFMANN, Pflanzen-phänologische Beobachtungen in Europa, Giessen, 1885.

EBERMEYER, Die physikalischen Einwirkungen des Waldes auf Luft und Boden, Aschaffenburg, 1873.

EBERMEYER, Beschaffenheit der Waldluft und die Bedeutung der Kohlensaure für die Waldvegetation, Stuttgart, 1885.

CORRESPONDENCE.

To the Editors of the American Meteorological Journal: —

In your recently published article on "The Mountain Meteorological Stations of the United States" the statement is made on page 397 (Vol VIII.), that the station on Mt. Washington remained unoccupied throughout the year 1891. I have heard from several sources, and am of the opinion, that the station was in operation last summer the same as on three previous years, and will ask you if such was not the case?

I would like also to call your attention to another mountain station, as it was not mentioned in the said article. A meteorological station was established on the summit of Mt. Killington in the summer of 1889, by Mr. W. M. Wilson, then an enlisted man in the Signal Corps, and the station has been open each year since then. The mountain has an elevation of about 4,380 feet, and, with the exception of the stations at Pike's Peak and Mt. Washington, is, I believe, the highest mountain meteorological station in the country.

W. S. CURRIER.

UNITED STATES WEATHER BUREAU,
CLEVELAND, OHIO, Feb. 25, 1892.

NOTE. — Mr. Currier is correct in stating that the station on Mt. Washington was in operation during the summer of 1891. The other station referred to is on Mt. Killington, Vermont, at an elevation of 4,056 feet. It is of the second order, making two eye observations daily, was established July 13, 1889, and has been maintained during the summer months since that time. The same is true of the station on Green Mountain, Mount Desert Island, Maine.

A. L. ROTCH.

ERRATA.

Dr. Woeikof has sent the following corrections of misprints which appeared in his paper on Cold Waves in the December of the JOURNAL: —

Page 376, lines 18–21 above, "That the air would be in unstable equilibrium more that 1.6° Fahrenheit, in 300 feet"; should read, "That the air would be in unstable equilibrium, *i. e.*, that the decrease of temperature with the height should exceed 1.6° Fahrenheit in 300 feet."

Page 377, line 6 above, "The windy," should read "In windy."

Page 377, line 9 above, "The mean rate of increase of temperature," should read, "The mean rate of decrease of temperature."

Page 377, line 5 below, "Increase of temperature," should read, "Decrease of temperature."

Page 378, line 2 above, "Colder period," should read, "Older period."

Page 378, line 4 above, "Colder than the peak in," should read, "Colder than the peak in %."

Page 378, line 2 after table, "Pike's Peak colder than Denver," should read, "Pike's Peak warmer than Denver."

Page 378, line 8 after table, "Sounblick 1,900 feet above valleys," should read, "Sounblick 9,000 feet above valleys."

Page 380, line 6 above, "Cold wave prevents cooling by radiation," should read, "Cold wave promotes cooling by radiation."

Page 381, lines 1–2 above, "Out of twenty-three cases of a pressure of 30.5, the top of Mt. Washington was warmer than Portland," should read, "Out of twenty-three cases of a pressure of 30.5 in four Mt. Washington was warmer than Portland."

Page 381, line 20 above, "The air colder more than twenty-four hours," should read, "The air calm more than twenty-four hours."

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